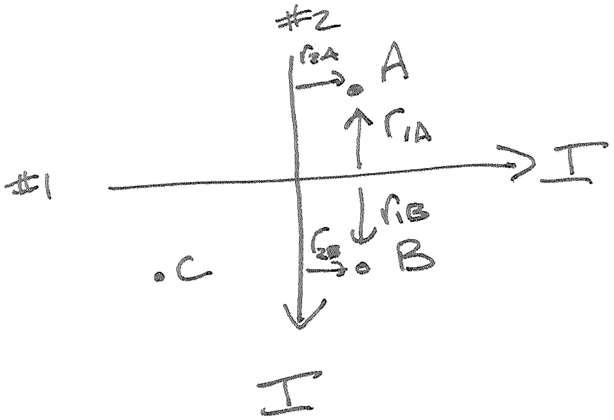
Physics 152, HW#6

Mastering Physics: 10 Questions From Chapter 24

Two written Questions

Magnetic Field Due to A Wire



$$\vec{B}_{net} = \vec{B}_1 + \vec{B}_2$$

$\vec{B}_1$: Due to #1 $\vec{B}_2$: Due to #2

A:
From RHR $\vec{B}_{1A}$ is ⊙ $\vec{B}_{2A}$ is ⊙

so $\vec{B}_{net}$ is ⊙ too

B: From RHR $\vec{B}_{1B}$ is ⊗ $\vec{B}_{2B}$ is ⊙

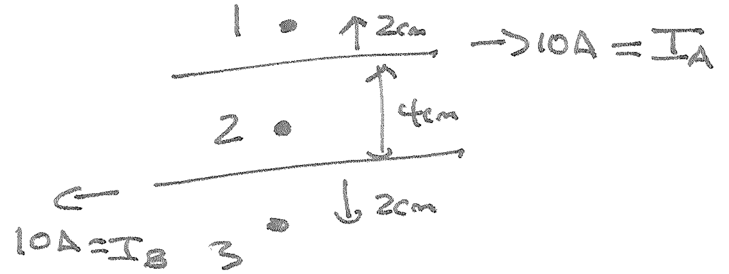
$B = \frac{\mu_0 I}{2\pi r}$ At B r_{1B} and r_{2B} are both 2 units

$\Rightarrow B_1 = B_2$ so $B_{net} = 0$

C: From RHR $\vec{B}_{1C}$ is ⊗ $\vec{B}_{2C}$ is ⊗

so $\vec{B}_{net}$ is ⊗ too

24.6



Call top current I_A

And Bottom I_B

$\Rightarrow \vec{B}_{NET} = \vec{B}_A + \vec{B}_B$

Point 1: From RHR, $\vec{B}_A$ is $\odot$, $\vec{B}_B$ is $\otimes$. Let $\odot$ be positive

$\Rightarrow B_{NET} = B_A - B_B$. Long wire $\Rightarrow B = \frac{\mu_0 I}{2\pi r} = \frac{(2\times10^{-7})I}{r}$

at 1: $r_A = 2cm = .02m \Rightarrow B_A = \frac{(2\times10^{-7}\,T\cdot m/A)(10A)}{(.02m)} = 1\times10^{-4}T$

$r_B = 4cm + 2cm = 6cm = .06m \Rightarrow B_B = \frac{(2\times10^{-7}\,T\cdot m/A)(10A)}{(.06m)} = \frac{1}{3}\times10^{-4}T$

$\therefore B_{net} = 1\times10^{-4}T - \frac{1}{3}\times10^{-4}T = \frac{2}{3}\times10^{-4}T = 0.666..\times10^{-4}T = 6.7\times10^{-5}T$

$\therefore \vec{B}_{net} = 6.7\times10^{-5}T, \odot$

Point 2: RHR $\Rightarrow \vec{B}_A$ is $\otimes$, $\vec{B}_B$ is $\otimes$

Making $\otimes$ positive $\Rightarrow B_{net} = B_A + B_B$

at 2 $r_A = 2cm = .02m$, $r_B = 2cm = .02m \Rightarrow B_A = B_B = \frac{(2\times10^{-7}\,T\cdot m/A)(10A)}{(.02m)} = 1\times10^{-4}T$

$\therefore \vec{B}_{net} = 2\times10^{-4}T, \otimes$

Point 3: RHR $\Rightarrow \vec{B}_A$ is $\otimes$, $\vec{B}_B$ is $\odot$

Letting $\odot$ be positive $\Rightarrow B_{net} = B_B - B_A$

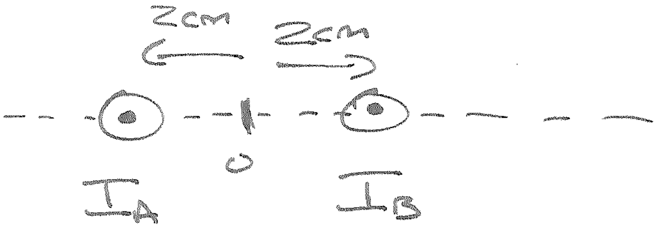
at 3, $r_B = 2\,cm \Rightarrow B_B = 1 \times 10^{-4}\,T$

$r_A = 6\,cm \Rightarrow B_A = \frac{1}{3} \times 10^{-4}\,T$

So $B_{net} = 1 \times 10^{-4}\,T - \frac{1}{3} \times 10^{-4}\,T = \frac{2}{3} \times 10^{-4}\,T = 6.7 \times 10^{-5}\,T$

& $\vec{B}_{net} = 6.7 \times 10^{-5}\,T$, $\odot$

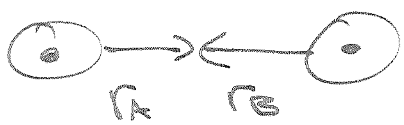
24.10



a) Current in same direction

$I_A = 4A$, $I_B = 3.5A$

By RHR, in region between wire $\vec{B}_A$ is ↑ and $\vec{B}_B$ is ↓ $\Rightarrow$ $\vec{B}_{net}$ can be zero where $B_A = B_B$



$$B = \frac{\mu_0 I}{2\pi r} \Rightarrow \frac{\mu_0 I_A}{2\pi r_A} = \frac{\mu_0 I_B}{2\pi r_B}$$

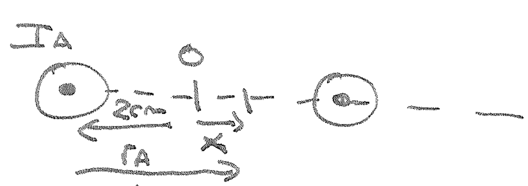
$$\Rightarrow I_A r_B = I_B r_A \Rightarrow r_B = \frac{I_B}{I_A} r_A$$

$$\Rightarrow r_B = \frac{3.5A}{4A} r_A = 0.875 r_A$$

We know $r_A + r_B = 4cm \Rightarrow r_A + .875 r_A = 4cm \Rightarrow r_A = \frac{4cm}{1.875}$

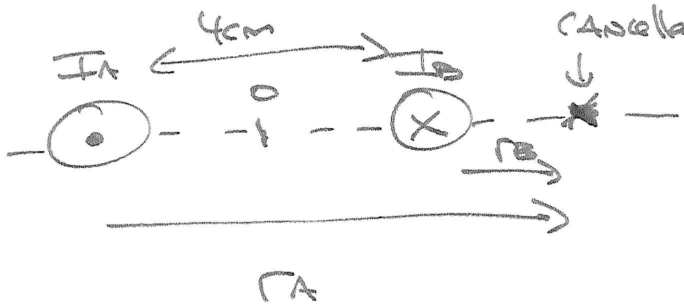
$= 2.1333cm$

r_A = Distance from I_A. Mastering wants x = Distance from Center



$x = r_A - 2cm = 0.133cm = 0.13cm$

b) IF currents ARE in opposite Directions:



RHR ⇒ To Right of I_B is where $\vec{B}_A = \downarrow$ AND $\vec{B}_B = \uparrow$ so they can cancel.

$B_A = B_B \Rightarrow r_B = 0.875 r_A$ still

Now $r_B = r_A - 4cm \Rightarrow r_A - 4cm = 0.875 r_A$

$\Rightarrow r_A(1 - 0.875) = 4cm \Rightarrow r_A = \frac{4cm}{0.125} = 32cm$

$X = r_A - 2cm = 30cm$

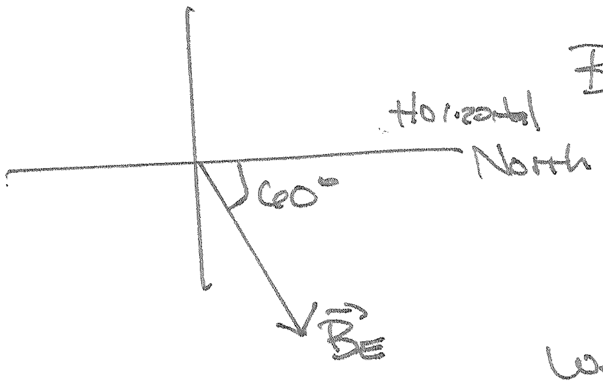
27. 15 $B_{brain} = 3\times10^{-12}\,T$, Brain = loop with diameter 16cm

Current loop $\Rightarrow$ $B = \dfrac{\mu_0 I}{2r}$

$2r = \text{diameter} = 16cm = 0.16m$

$$I = \frac{B(2r)}{\mu_0} = \frac{(3\times10^{-12}\,T)(0.16m)}{4\pi(1\times10^{-7}\,Tm/A)} = 3.8\times10^{-7}A$$

24.53



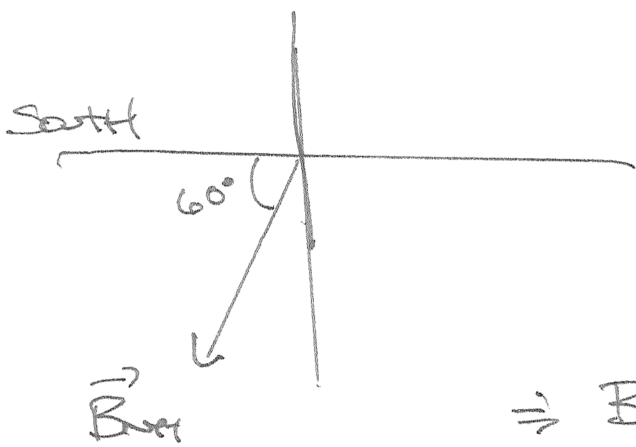
$B_E = 50\,\mu T \Leftarrow$ Earth's field

$= 50(1\times10^{-6})T$

$= 5\times10^{-5}T$

We make 50-turn coil
80cm diameter $\Rightarrow$ 40cm radius

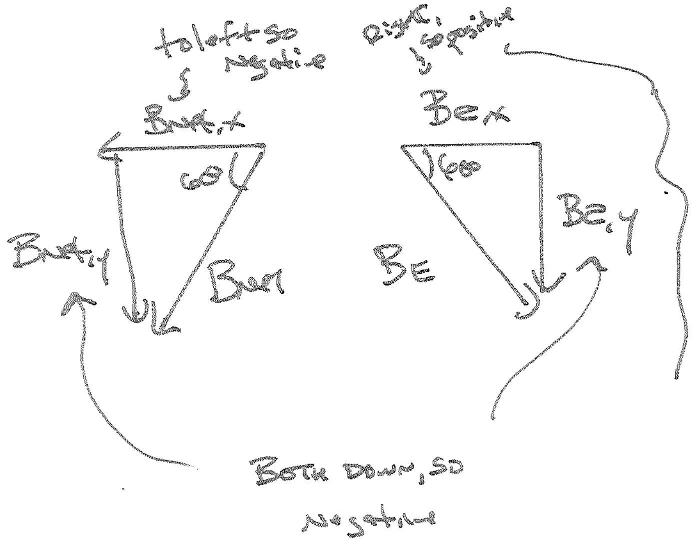
We want to make



$B_{net} = 50\,\mu T$

$\vec{B}_{net} = \vec{B}_E + \vec{B}_{coil}$

$\Rightarrow B_{net,x} = B_{E,x} + B_{coil,x}$



$\Rightarrow -50\,\mu T\cos 60° = 50\,\mu T\cos 60° + B_{coil,x}$

$\Rightarrow -50\,\mu T\left(\frac{1}{2}\right) = 50\,\mu T\left(\frac{1}{2}\right) + B_{coil,x}$

$\Rightarrow B_{coil,x} = -50\,\mu T\left(\frac{1}{2}\right) - 50\,\mu T\left(\frac{1}{2}\right)$

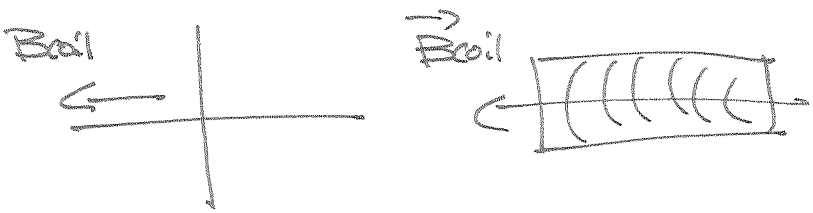
$= -50\,\mu T$

IN THE SAME WAY: $B_{net,y} = B_{E,y} + B_{coil,y}$

$$\Rightarrow -50\mu T \sin 60^\circ = -50\mu T \sin 60^\circ + B_{coil,y}$$

$$\Rightarrow B_{coil,y} = -50\mu T \sin 60^\circ + 50\mu T \sin 60^\circ = 0$$

$\Rightarrow$ no y-component, so $B_{coil} = B_{coil,x} = -50\mu T \Rightarrow 50\mu T$ to the South

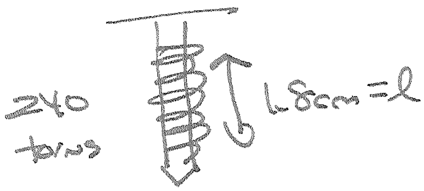


So Coil Needs to have its Axis Horizontal AND Directed South-North.

b) What Current? THE problem keeps Referring to this as A "Coil". THAT Along with the lack of length given tells us that we are to Assume that this is not A Solenoid. We CAN, instead, use the equation for the Single Current loop. $B = \frac{\mu_0 I}{2r}$ AND multiply by # of loops, N. $B = \frac{N\mu_0 I}{2r} \Rightarrow I = \frac{B(2r)}{N\mu_0}$

$$\therefore I_{coil} = \frac{(5\times10^{-5}T)(\overset{80cm}{0.8m})}{(50)(4\pi)(1\times10^{-7}T\cdot m/A)} = 0.64A$$

24.57



$I = 0.54A$

Nail increases B by 100.

$l = 1.8cm = 0.018m$

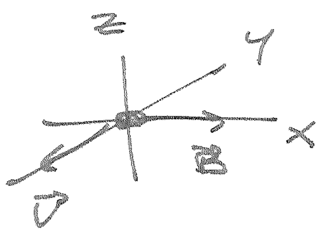
Here given # turns AND length ∴ Solenoid

$$\therefore B = \mu_0 \frac{N}{l} I = 4\pi (1\times10^{-7}\, T\cdot m/A)\left(\frac{240}{0.018m}\right)(0.54A) \approx 0.009T$$

without NAil

With Nail $B = 100(0.009T) = 0.9\,T$

24.23



electron ⇒ $|q| = 1.6\times10^{-19}C$

$V = 4.5\times10^{7} m/s$

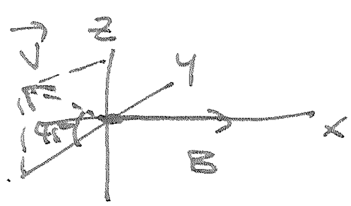
$B = 0.3T$

a) $F = |q|vB\sin\alpha$ $\vec{v}$ along $-y$ axis, $\vec{B}$ along x ⇒ $\alpha = 90°$

∴ $F = |q|vB\sin 90° = |q|vB = (1.6\times10^{-19}C)(4.5\times10^{7}m/s)(0.3T)$

⇒ $F = 2.16\times10^{-12}N = 2.2\times10^{-12}N$

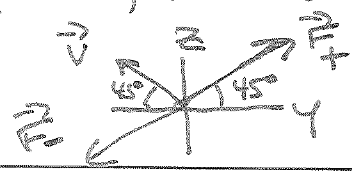
b) direction RHR ⇒ A positive charge would feel force in $+z$ direction, so electron feels force in z Direction



$\vec{v}$ in y-z plane, $\vec{B}$ along x ⇒ $\alpha = 90°$ still

⇒ $F = 2.2\times10^{-12}N$

By RHR, $\vec{F}$ is 90° to $\vec{v}$ and $\vec{B}$ ⇒ in z-y plane to be 90° to $\vec{B}$



So $\vec{F}_+$ at $+45°$ in z-y plane for positive charge but 135° for negative electron ⇒ "$-zy$ Direction"

24.30

Deuterium

• • • • $\longrightarrow$ $M = 3.34\times10^{-27}\,kg$

$K = 5\,MeV$

a.) SPEED? $K = \frac{1}{2}Mv^2$ Relates Kinetic Energy And Speed.

But we have to use Joules as the unit

$\Rightarrow K = 5\,MeV = 5(\times10^{6})\,eV = 5\times10^{6}\,eV = 5\times10^{6}\,eV \times \dfrac{1.6\times10^{-19}\,J}{eV}$

$M = Mega = 10^{6}$

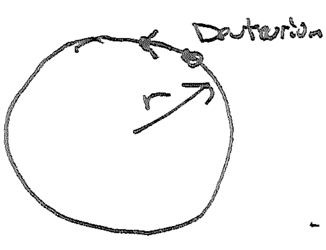
$\Rightarrow K = 8\times10^{-13}\,J$

$K = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\dfrac{2K}{M}} = \sqrt{\dfrac{2(8\times10^{-13}\,J)}{3.34\times10^{-27}\,kg}} = \sqrt{4.79\times10^{14}\,m^2/s^2}$

$= \underline{\underline{2.19\times10^{7}\,m/s}}$

Unit: $\dfrac{J}{kg} = \dfrac{kg\cdot m^2/s^2}{kg}$

b) Diameter of largest orbit in magnetic field of 1.25T?



in magnetic field $r = \dfrac{mv}{|q|B}$. Deuterium ions have one proton & one neutron $\rightarrow q = 1.6\times10^{-19}\,C$

$\therefore r = \dfrac{(3.34\times10^{-27}\,kg)(2.19\times10^{7}\,m/s)}{(1.6\times10^{-19}\,C)(1.25\,T)} = 0.3655\,m$ $\Rightarrow$ diameter $= 2\times r = 0.731\,m$

c) IF "Current" is $400 \mu A$, how many deuterium per second.

By Current here, we mean how much charge is moving through the beam with time, i.e. $I = \frac{\Delta q}{\Delta t}$

$I = 400 \mu A = 400 \times 10^{-6} A = 4 \times 10^{-4} A$, $\Delta t = 1s$

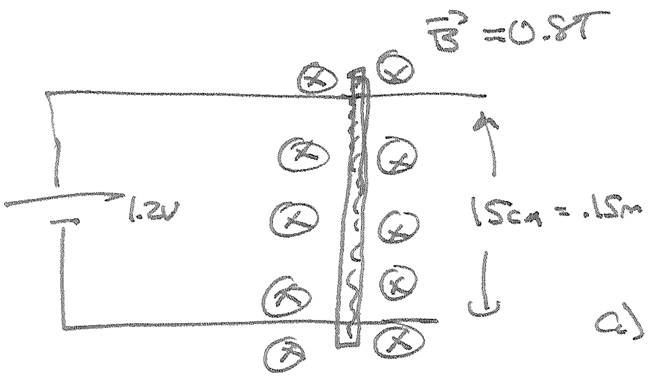
$\Rightarrow \Delta q = (4 \times 10^{-4} A)(1s) = 4 \times 10^{-4} C$ (unit: $A \cdot s = \frac{C}{s} \cdot s = C$)

Each deuterium has charge $1.6 \times 10^{-19} C$

$\Rightarrow \underset{\substack{\uparrow \\ \text{Number of deuterium}}}{\Delta q = N} (1.6 \times 10^{-19} C) \Rightarrow N = \frac{\Delta q}{1.6 \times 10^{-19} C} = \frac{4 \times 10^{-4} C}{1.6 \times 10^{-19} C}$

$= \underline{\underline{2.5 \times 10^{15}}}$

24.48 — Railgun



$\mathcal{E} = 1.2V$, $R = 0.71 m\Omega = 0.71(1\times10^{-3}\Omega)$
$= 7.1\times10^{-4}\Omega$

$m = 5.3g = 5.3\times10^{-3} kg$

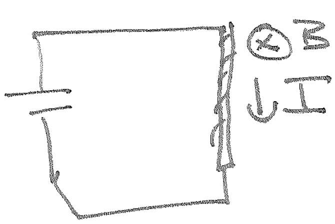
a) What is Current?

$\Delta V = IR$. Ignoring Resistance of Rails ⇒ Single Resistor

$\Rightarrow \Delta V = \mathcal{E}$

$\Rightarrow I = \frac{\mathcal{E}}{R} = \frac{1.2V}{7.1\times10^{-4}\Omega} = 1690A = 1700A$ to 2 sig figs

b) Direction of force? Current Flows from High to low Potential



By RHR $\vec{F}$ is to the Right

c) $F = IlB\sin\alpha$ I is ↓, $\vec{B}$ is ⊗ → $\alpha = 90°$; $\sin 90° = 1$

$\Rightarrow F = IlB = (1700A)(0.15m)(0.8T) = \cancel{202.8}\ 204 N = 200N$

d) Ignoring Friction $\Rightarrow$ 200N is only force in x-direction

→ speed after sliding 7.8cm = 0.078m

$\sum F_x = ma_x \Rightarrow 200N = (5.3\times10^{-3}kg)\, a_x$

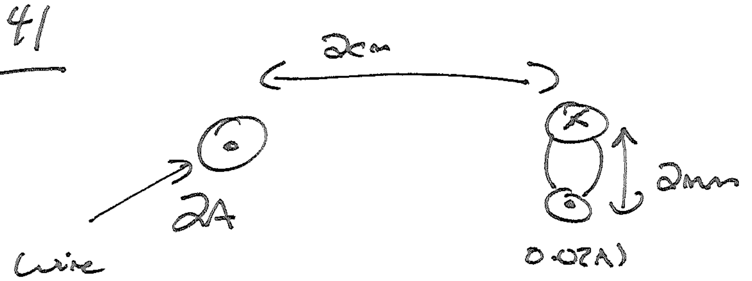
$\Rightarrow a_x = \frac{200N}{5.3\times10^{-3}kg} = 37736 m/s^2$ ← constant

$V_x^2 = V_{0x}^2 + 2a_x(x-x_0) \Rightarrow V_x^2 = 0 + 2(37736 m/s^2)(0.078m)$

$\Rightarrow V_x^2 = 5886.8 m^2/s^2 \Rightarrow V_x = \sqrt{5886.8 m^2/s^2} =$

$76.7 m/s = 77 m/s$

24.41

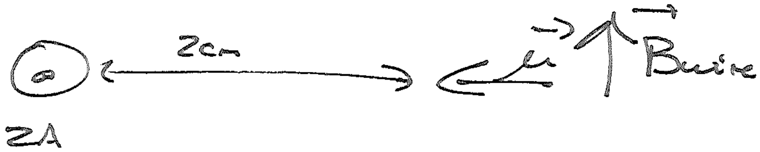


RADius of loop is $1mm = 1 \times 10^{-3} m$

A Loop's Dipole moment is initially TO THE LEFT since RHR tells us to curl of our fingers in the direction of loop's current (into page on top AND out of page on Bottom.)

$\mu = I_{coil} A = (0.02A)\pi(1\times10^{-3}m)^2 = 6.283\times10^{-8} A\cdot m^2$

B



Long wire $\Rightarrow$ $B_{wire} = \frac{\mu_0 I}{2\pi r}$

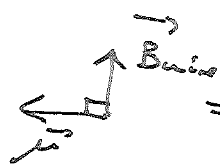
$\Rightarrow B_{wire} = \frac{2\times10^{-7} I}{r}$ $\quad I$ = wire's current $= 2A$

$r = 2cm = 0.02m$

$\Rightarrow B_{wire} = \frac{(2\times10^{-7}T\cdot m/A)(2A)}{0.02m} = 2\times10^{-5}T$

Pointing Thumb out of page tells us $\vec{B}_{wire}$ points up

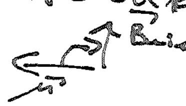
$\tau = \mu B_{wire} \sin\phi$ $\quad \phi$ is Angle Between $\vec{\mu}$ & $\vec{B}_{wire}$



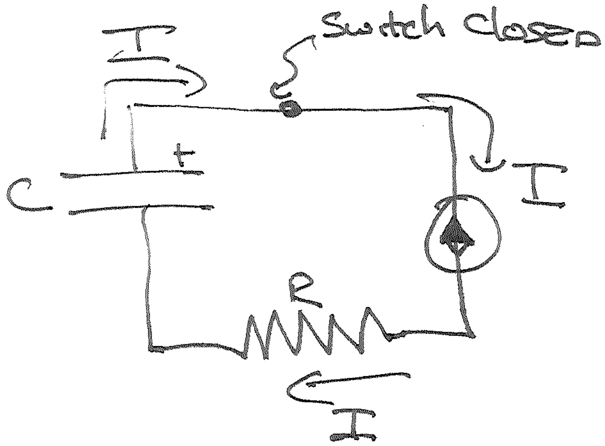
$\Rightarrow \phi = 90°$

$\sin 90° = 0 \Rightarrow \tau = (6.283\times10^{-8}Am^2)(2\times10^{-5}T) = 1.257\times10^{-12} A\cdot m^2 = 1.3\times10^{-12} A\cdot m^2$

C Loop Rotates to align $\vec{\mu}$ with B_{wire} $\Rightarrow$ it will rotate Clockwise by 90°



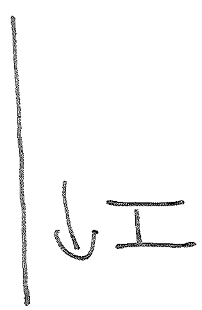
WRITTEN QUESTION:



$C = 1F,\ R = 2\Omega$

a) What DIRECTION is magnetic FIELD at COMPASS? When switch is closed CURRENT FLOWS AS CAPACITOR DISCHARGES. JUST LIKE WITH a battery Current Flows From positive to Negative ⇒ Clockwise through CIRCUIT AS SHOWN ABOVE.

Compass only Affected by Field created by wire Below it ⇒ STRAIGHT WIRE with CURRENT FLOWING DOWNWARD.



RHR tells us that above the wire (where Compass is), $\vec{B}$ points to the left

$\overleftarrow{\quad}$ $\vec{B}$.

b.) WHAT is Magnitude of Field at different times?

FOR THE long wire $B = \frac{\mu_0 I}{2\pi r} = \frac{(2\times10^{-7}) I}{r}$

$r = 1\,cm = 0.01\,m$, the current is changing with time.

& Discharging Capacitor $\Rightarrow I = I_0 e^{-t/\tau}$

$I_0 = \frac{\Delta V_C}{R} = \frac{50V}{2\Omega} = 25A$, $\tau = RC = (2\Omega)(1F) = 2s$.

~~I THINK I'll do~~

At $t = 0$, $I = I_0 = 25A$ $\Rightarrow B = \frac{(2\times10^{-7}\,T\cdot m/A)(25A)}{(0.01m)} = 5\times10^{-4}\,T$

So $\frac{B}{B_E} = \frac{5\times10^{-4}\,T}{50\times10^{-6}} = 10$

At $t = 2s$, $I = I_0 e^{-t/\tau} = 25e^{-2/2} = 25e^{-1} = 25(0.3679)$
$= 9.20A$

So $B = \frac{(2\times10^{-7})(9.20A)}{0.01m} = 1.84\times10^{-4}\,T$, $\frac{B}{B_E} = \frac{1.84\times10^{-4}}{50\times10^{-6}\,T} = 3.679$
$= 3.7$

At $t = 4s$, $I = I_0 e^{-t/\tau} = 25e^{-4/2} = 25e^{-2} = 25(0.1353)$

$= 3.38A$

$B = \frac{(2\times10^{-7})(3.38A)}{0.01m} = 6.77\times10^{-5}T$, $\frac{B}{B_E} = \frac{6.77\times10^{-5}T}{50\times10^{-6}T} = 1.35$

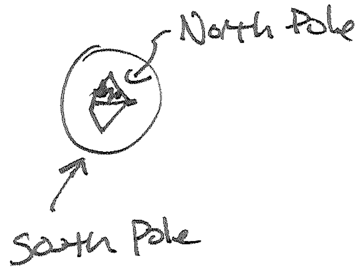
At $t = 10s$, $I = 25e^{-10/2} = 25e^{-5} = 25(0.0067) = 0.168A$

$B = \frac{(2\times10^{-7})(0.168A)}{0.01m} = 3.37\times10^{-6}T$, $\frac{B}{B_E} = \frac{3.37\times10^{-6}T}{50\times10^{-6}T} = 0.067$

IN SUMMARY (AND using 2 sig figs)

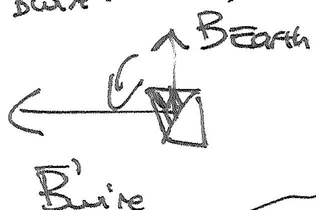
$t(s)$	$I(A)$	$B(T)$	B/B_E
0	25	5×10^{-4}	10
2	9.2	1.8×10^{-4}	3.7
4	3.4	6.8×10^{-5}	1.4
10	0.17	3.4×10^{-6}	0.07

c.) THE COMPASS'S NEEDLE Starts IN THE DIRECTION of the earth's FIELD.



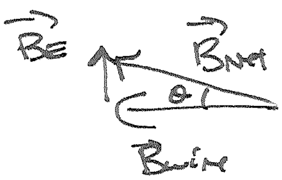
But A compass's North pole will point in the direction of any magnetic field, so when we turn on the circuit, the needle will ~~swing to the Right Left~~ rotate counter clockwise towards the wire's FIELD.

NEEDLE ROTATING towards $\vec{B}_{wire}$:



the wire's FIELD is Much stronger than Earth's FIELD so Much stronger force to Left.

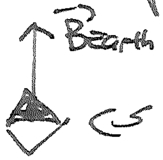
(To be super precise



at $t=0$ $B_{wire} = 10 B_e$ $\Rightarrow \tan\theta = \frac{B_E}{B_{wire}} = \frac{1}{10}$

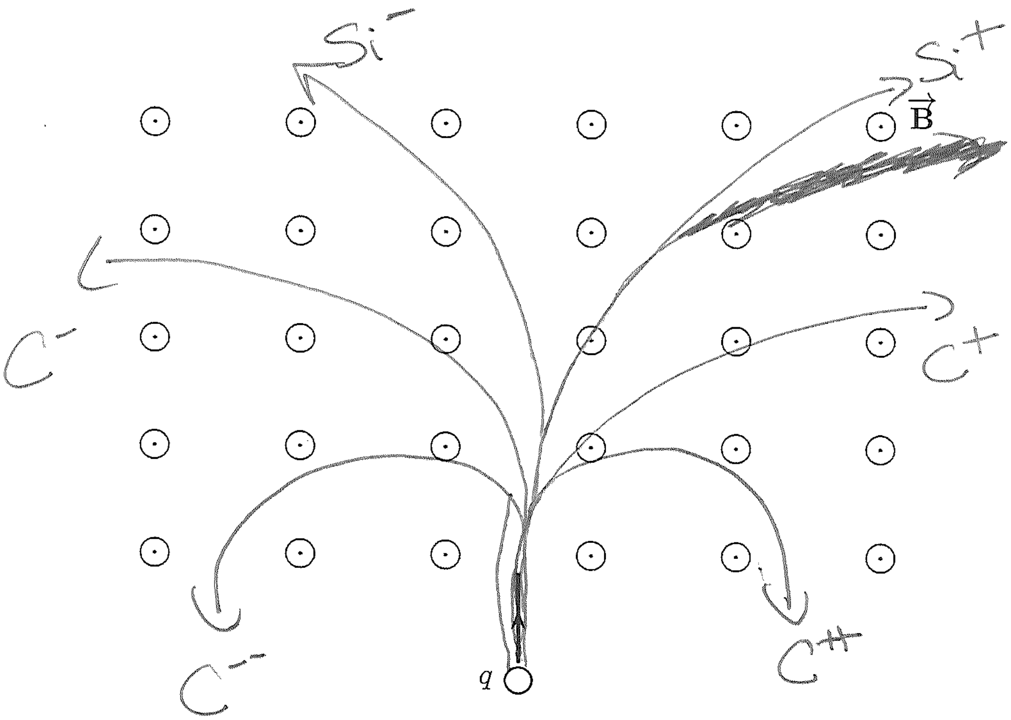
$\Rightarrow \theta = \tan^{-1}\left(\frac{1}{10}\right) = 5.71°$, NEEDLE will swing counterclockwise trying to get to 5.71° Above Negative X-AXIS. It won't make it there though Because the ~~Be~~ wire's Field is decreasing with time).

As wire's Field weakens with time, the Needle will Reverse direction AND Swing BACK to pointing in direction of the earth's magnetic FIELD.



← FINAL position of NEEDLE

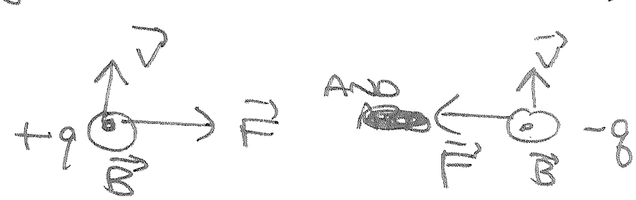
Written Question #2: The picture shows the trajectory of an ion, initially moving upwards, entering a region of space where there is a uniform magnetic field pointing out of the page. If the initial speed of each ion is the same, sketch a possible trajectory for each of the ions given in the table. Your trajectories do not need to be perfectly to scale, but they should have correct directions, ~~and~~ fill most of the available space, AND must be labeled. Explain how you determined your answer. **Hints:** The notation used is the typical chemistry one. C^+ is a carbon atom which has lost one electron, C^- has gained one extra electron, and so forth.



	Ion		Ion
(a.)	C^+	(b.)	C^-
(c.)	C^{++}	(d.)	C^{--}
(e.)	Si^+	(f.)	Si^-

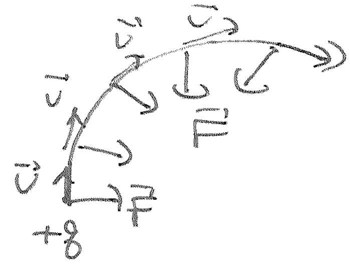
UNIFORM MAGNETIC FIELD AND MOVING CHARGED PARTICLES ⇒ UNIFORM CIRCULAR MOTION OF RADIUS $r = \frac{mv}{|q|B}$.

All CARBON IONS HAVE SAME MASS. AND speed AND $|q|$ ⇒ THE RADIUS FOR C^+ AND C^- will BE THE SAME. But THEY will CIRCLE IN opposite directions. THE FORCE RHR (Curl fingers FROM $\vec{v}$ to $\vec{B}$, THUMB $= \vec{F}$) tells us THAT THE INITIAL FORCE IS



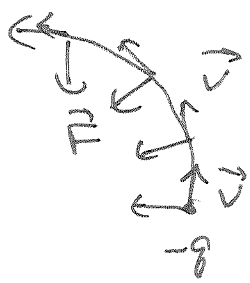
(CONT)

(As velocities change so does force to cause circular motion. For $+q$:



AND

For $-q$:



)

So C^+ circles clockwise while C^- circles CCW.

(CW for C^{++}, CCW for C^{--})

C^{++} AND C^{--} ~~Also~~ circle in THE SAME WAY since they have the same type of charge but $r = \frac{mv}{|q|B}$ ⇒ their circles have smaller radius. (HALF AS much if you WANT TO BE precise.)

more charge ⇒ smaller radius

Finally Si^+ being positive ⇒ clockwise, Si^- being negative ⇒ counterclockwise. But silicon atoms have more mass than carbon atoms. $r = \frac{mv}{|q|B}$ ← more mass ⇒ larger radius for more mass. (Carbon has atomic mass of 12 and Silicon 28 ⇒ then Silicon's radius is 2.333.. × larger. But you don't have to be that careful.)